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FOREIGN TECHNOLOGY DIVISION

INFRARED HOMING GUIDANCE

by

Yue Min

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INFRARED HOMING GUIDANCE

by Yue Min

Infrared homing guidance is a passive guidance method which, compared to optical and radar guidance methods, has the advantages of being easy to conceal, homing accuracy is high, and installation on a missile is simple and reliable. This article briefly relates the general operating principles and trends of development of air-to-air missile infrared homing guidance equipment.

Rattlesnakes have the ability to make lightning-like attacks in the dark of night on small creatures such as birds and mice and will devour them. We know that even though the eyes of these snakes are round and bright their eyesight is not good, particularly at night, and furthermore they cannot depend on their eyes for catching food. They evidently catch these kinds of warm-blooded small animals by looking for suitable surrounding temperatures, relying on a special sense organ - an infrared or thermal receptor. Inside this infrared receptor in the rattlesnake's head there are special nerve cells which can use the stimulus of minute external temperature changes (such as temperature changes of 0.001°C) to determine the location of the quarry. This infrared receptor is actually the detection and homing system of certain snakes. This has given man an inspiration: Couldn't a detection and homing system like that of the snake also be used on air-to-air missiles?

Along with the rapid development of photoelectric technology and detection devices over the last thirty years since World War II, various countries of the world have already successfully used infrared homing guidance systems, similar to that of the rattlesnake, on air-to-air missiles to detect infrared radiation from targets and to direct the missile to a hit on the target (see Fig. 1.). In the early 1950's the United States developed the successful "Sidewinder" air-to-air missile and this is how it got its name [See Translator Note].

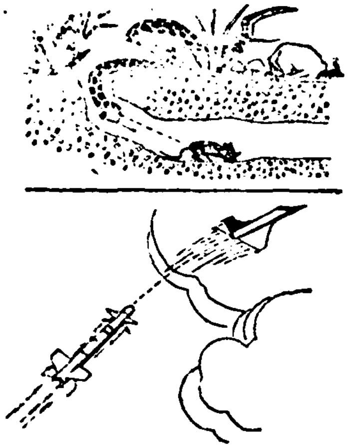

Fig. 1. Top: Rattlesnake senses temperature changes and pursues mouse.
Bottom: Air-to-air missile guided by infrared homing.

PRINCIPLES OF OPERATION

Air-to-air missiles have three types of homing guidance methods: the stern chase method, the parallel approach method, and the proportional homing method. When homing by the stern chase method, overloading of the missile is rather great and therefore this method is not used in homing guidance missiles. The parallel approach method is a rather ideal homing method, Overloading of the missile is rather low, but realization is rather difficult, it requiring a gyrostabilized platform, and therefore up to now we have yet to see missiles using this type of homing method. Overloading of the missile is relatively slight when the proportional homing method is used and the equipment is rather simple, having only an angle measuring system and a gyrotracking system, therefore this type of homing method has gained widespread use. For example, the U. S. "Sidewinder", the British

[TRANSLATOR'S NOTE: The Chinese word for "rattlesnake" is used to designate the U. S. "Sidewinder" missile, "sidewinder" being a type of rattlesnake and there being no other equivalent term in Chinese.

"Red Top", and the French "Matra" air-to-air missiles all use the proportional homing method.

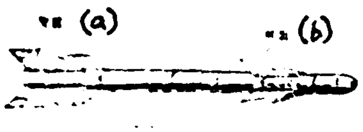

Fig. 2. (1) infrared homing head; (2) control surfaces; (3) detonator and warhead; (4) engine

KEY: (a) tail; (b) control surfaces

The configuration of a typical air-to-air missile is shown in Figure 2. The missile is commonly divided into four sections: the first section is the infrared homing head (i.e., infrared homing guidance equipment); the second second is the control surfaces; sections one and two form the control system section; section three is the detonator and warhead; section four is the engine. The infrared homing head receives infrared radiation coming from the target and converts it into electrical signals. These signals are in direct ratio to the speed of turning of the line of sight of the target, see Figure 3. These signals are used to control the deflection of the control surfaces. Two pairs of control surfaces are mounted separately in two planes perpendicular to each other and two servos separately control the two pairs of control surfaces, and deflecting the control surfaces makes it possible to control the missile's flight toward the target.

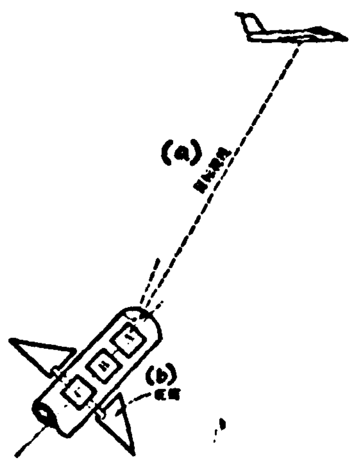

Fig. 3. Missile tracking a target.

A - senses infrared rays; B - converts into electrical signals and amplifies; C - controls the deflection of control surfaces

KEY: (a) target line of sight; (b) control surfaces

In order to guage the turning speed of the line of sight of the target, the homing head must track the target and therefore the basic task of the infrared homing head is tracking the target and measuring the turning speed of the line of sight of the target. If fact, the infrared homing head position indicator is only able to measure the included angle Δq between the target line of sight and the optical system axis and at that moment the output signals are directly proportional to angle Δq. These signals are sent to the gyrotracking mechanism, making the the optical systém continuously track the target. The speed of turning of the optical system axis is directly proportional to the homing head output signals, and under stable tracking conditions the speed of turning of the optical system axis is equal to that of the line of sight of the target and therefore the homing head output signals can be regarded as directly proportional to the speed of turning of the line of sight of the target.

COMPONENTS

An infrared homing head tracking the course of a flying target is somewhat similar to a hunter tracking a rabbit. After the hunter spots the rabbit, his eyes must remained fixed on the rabbit. Information on the rabbit's direction of movement and speed is relayed to the brain. Based on this information, the brain, on the one hand, must control the turning of the hunter's head and make the eyes remain fixed on the rabbit. And on the other hand, it must control the feet running after the rabbit and, upon approaching to a certain distance, the hunter's raising the rifle and shooting the rabbit. The infrared homing head is only the eyes and the brain of an air-to-air missile tracking, pursuing, and attacking the target. It is composed of the following components.

1. Optical system. It initiates the operation of the "eyes" and dispersed, relatively weak radiation energy is concentrated into an image for use in detecting the target; at the same time, since the optical system object and image have a one-to-one relationship, the position of the picture point on the image plane will respond to the

bearing of the target in space.

2. <u>Target radiation energy detector</u>. This is a photoconducting cell which corresponds to the retina of the eye.

When infrared rays shine on the light sensitive layer of the lead sulfide photoconducting cells used in the infrared homing head of an air-to-air missile, a change occurs in the resistance value of the output terminals. Different photoconducting cells have different sensitivities to infrared radiation of various wavelengths. For example, lead sulfide photoconducting cells have the greatest sensitivity to incident radiation of 2.4~2.5 meters. Therefore when selecting photoconducting cells, the sensitive waveband range and the maximum value range of target radiation energy should be made to coincide with each other as much as possible. In order to detect target radiation of 3~5 μm, silver antimonide detectors are used in some air-to-air missiles.

3. <u>Modulation disk.</u> From the requirement for homing heads to track the target and control the missile, we can see that the amplitude of the signals put out by the photoconducting cells should follow the size and change in target deviation from the optical axis. At the same time, it is also necessary that the phase energy of the output voltage reflect the bearing of the target. Thus it is necessary for the the incoming infrared radiation energy from the target to be modulated according to the size and direction of target deviation from the optical axis. This task is accomplished by placing a modulation disk on the optical system collector surface.

4. <u>Electronic circuits</u>. Their function is amplifying the relatively weak electrical signals coming from the photoconducting cells and converting them into usable control signals.

The signals put out by the electronic circuits are divided into 2 circuits: one circuit feeds the tracking mechanism which drives the optical axis and continuously aims it at the target and this achieves the goal of tracking the target. The other circuit feeds the servos which drive the control surfaces, controlling the direction of the missile's flight and steering the missile into the target.

5. Tracking mechanism. The infrared homing head tracking mechanism normally employs quite a few gyroscopes with three degrees of freedom. This is due to gyroscopes with three degrees of freedom having two important features: a fixed axis and precession. The optical system is mounted on the rotor axis of a gyroscope with three degrees of freedom and the optical axis coincides with the rotor axis. When there is no target in the optical system, the photodetector does not put out a signal, the gyrodrive mechanism is unable to add momentum to the gyroscope and due to the fixed axis feature of the gyroscope there is no change in the position of the optical axis in space and thus the stability of the measuring reference is maintained. When a target is detected, the electronic circuit puts out an error signal, the gyrodrive mechanism applies a precessional moment of force to the gyroscope causing precessional motion of the gyroscope in the direction of the target. In short, so long as the target deviates slightly from the optical axis, there will be only error signal output which causes the optical axis to draw nearer the target and this achieves the goal of the homing head continuously tracking the target.

In the infrared homing heads of some air-to-air missiles, motors for both the azimuth and pitch directions are also used to drive the optical axis and track the target.

TRENDS OF DEVELOPMENT

In the past, air-to-air missiles have generally used a mode of attack which is carried out within a certain sector of the enemy plane's tail (tail chase). At present, air-to-air missiles have a revised attack mode whereby they carry out interception and frontal attacks, i.e., attacking from the side or head on, thus requiring a number of appropriate changes be made in the infrared homing head. First of all, in an interception or head-on attack, what the homing head is sensitive to is the energy radiated by the aircraft skin and standing wave points. The temperature of the skin and the standing wave points is much lower than that of the jet nozzle, therefore the energy they radiate is much weaker and the radiation wavelength is also somewhat longer. In order to detect this weak, long-wave radiation energy, lead sulfide photoconducting cells often satisfy the requirements but other suitable detectors must be used, for example, new types of detectors of antimonides of silver, tellurium, cadmium, mercury, etc., in order to increase the sensitivity of the detectors, yet provision must be made for detector cooling. In addition, it is also necessary that the optical system employ optical materials which pass long wave infrared rays.

In order to adapt to the requirements of modern air warfare, in recent years a type of close combat missile has been gradually developed which is suited to aerial combat between fighter aircraft. This type of missile is used by launching within aircraft cannon range. Since the range is short and the relative speed between the enemy aircraft and our aircraft is rather great, the homing head tracking mechanism must be quick and the angular velocity of tracking must be high and therefore improvements must be made in gyroscope construction to decrease its rotational inertia and increase its speed.

In order to adapt to the requirements of modern air warfare, the homing head itself must be able to automatically search for and automatically lock on the target, therefore the missile has to be equipped with a search signal producing circuit and an automatic detection and lock-on circuit. Employing rational detection circuits leads to the elimination of interference and increases the probability of locking on the target.

At present, France is engaged in serial production of the Matra 550 air-to-air missile which is a close combat missile. It can be launched at a range of 500 meters or can attack from a long distance behind. It uses an indium antimonide detector which uses nitrogen gas for cooling. It can automatically search for and automatically lock on the target.

Infrared thermal imagery technology which has developed rapidly in recent years will greatly advance the development of infrared guidance technology. Thermal imagery is the thermal radiation of the scenery in a given space being changed into a visible picture. The shape and appearance of the target and background show up clearly. Then the target is firmly trapped by the wave gate and the missile is guided to a hit on the target. In the future, when missiles employ thermal energy guidance they will not be used in daytime but in the pitch dark of night and will be able to carry out attacks with a greatly increased accuracy of hits.